10-25-04

93/2681/$

EXPRESS MAIL NO. EV 525475275 US

PATENT APPLICATION
Docket No: 15689.62

OIPE
OCT 22 2004
PATENT & TRADEMARK OFFICE

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re application of		)	
	Minami Ishii et al.	)	
Serial No.:	09/750,814	)	Art Unit 2681
Confirmation No.:	8262	)	
Filed:	December 28, 2000	)	
For:	PATH TIMING DETECTING METHOD IN MOBILE COMMUNICATIONS SYSTEM AND BASE STATION	)	
Customer No.:	022913	)	

INFORMATION DISCLOSURE STATEMENT UNDER 37 C.F.R. § 1.97

Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

Sir:

Please find, pursuant to 37 C.F.R. § 1.98(a)(1), the enclosed Form PTO-1449 which contains a list of all patents, publications, or other items that have come to the attention of one or more of the individuals designated in 37 C.F.R. § 1.56(c). While no representation is made that any of these references may be "prior art" within the meaning of that term under 35 U.S.C. §§ 102 or 103, the enclosed list of references is disclosed so as to fully comply with the duty of disclosure set forth in 37 C.F.R. § 1.56.

Moreover, while no representation is made that a specific search of office files or patent office records has been conducted or that no better art exists, the undersigned attorney of record

~~10/26/2004 AWONDAF1 00000044 09750814~~

~~01 FC:1806~~ ~~180.00 OP~~

10/26/2004 AWONDAF1 00000046 09750814

01 FC:1806 180.00 OP

believes that the enclosed art is the closest to the claimed invention (taken in its entirety) of which the undersigned is presently aware, and no art which is closer to the claimed invention (taken in its entirety) has been knowingly withheld.

In accordance with 37 C.F.R. §§ 1.97 and 1.98, a copy of each of the listed references or relevant portion thereof is also enclosed.

<u>Petition for Consideration</u>
<u>Under 37 C.F.R. § 1.97(d)</u>

In accordance with 37 C.F.R. § 1.97(d), a Promptness Certification, a Petition for Consideration of Information Disclosure Statement after Final Action or Notice of Allowance, and a PTO 2038 Credit Card form in the amount of $180.00 to cover the petition fee set forth in 37 C.F.R. § 1.17(i)(1) are enclosed to secure consideration of the references submitted with this Information Disclosure Statement. Please credit any over payment or charge any additional fees to Deposit Account No. 3-3178 of the undersigned.

DATED October 22, 2004.

Respectfully submitted,

Adrian J. Lee
Attorney for Applicant
Registration No. 42,785
Customer No. 022913

AJL: ds
DS0000002646V001

TRANSMITTAL OF INFORMATION DISCLOSURE STATEMENT (Under 37 CFR 1.97(d))	Docket No. 15689.62

In Re Application Of: **Minami Ishii et al.**

OIPE JC67
OCT 22 2004
PATENT & TRADEMARK OFFICE

Application No.	Filing Date	Examiner	Customer No.	Group Art Unit	Confirmation No.
09/750,814	December 28, 2000	Unknown	022913	2681	Unknown

Title: **PATH TIMING DETECTING METHOD IN MOBILE COMMUNICATIONS SYSTEM AND BASE STATION**

Address to:
Commissioner for Patents

The Information Disclosure Statement submitted herewith is being filed after the period specified in 37 CFR 1.97(c), and on or before payment of the issue fee, and is accompanied by the Statement as specified in 37 CFR 1.97(e) and the fee set forth in 37 CFR 1.17(p).

☐ A check in the amount of is attached.

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(Date)

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***This certificate may only be used if paying by deposit account.**

Signature

Adrian J. Lee
Reg. No.: 42,785
Attorney for Applicant

Dated: **October 22, 2004**

cc:

EXPRESS MAIL NO. EV 525475275 US

PATENT APPLICATION
Docket No: 15689.62

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re application of		
	Minami Ishii et al.	
Serial No.:	09/750,814	Art Unit 2681
Confirmation No.:	8262	
Filed:	December 28, 2000	
For:	PATH TIMING DETECTING METHOD IN MOBILE COMMUNICATIONS SYSTEM AND BASE STATION	
Customer No.:	022913	

PETITION FOR CONSIDERATION OF INFORMATION DISCLOSURE STATEMENT AFTER FINAL ACTION OR NOTICE OF ALLOWANCE

Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

Sir:

Pursuant to 37 C.F.R. § 1.97(d), I hereby request consideration of the accompanying Information Disclosure Statement.

Enclosed is PTO 2038 Credit Card form in the amount of $180.00.

Dated this 22nd day of October 2004.

Respectfully submitted,

Adrian J. Lee
Attorney for Applicant
Registration No. 42,785
Customer No. 022913

AJL:ds

EXPRESS MAIL NO. EV 525475275 US

PATENT APPLICATION
Docket No: 15689.62

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re application of		)
	Minami Ishii et al.	)
Serial No.:	09/750,814	) Art Unit 2681
Confirmation No.:	8262	)
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For:	PATH TIMING DETECTING METHOD IN MOBILE COMMUNICATIONS SYSTEM AND BASE STATION	)
Customer No.:	022913	)

PROMPTNESS CERTIFICATION
UNDER 37 C.F.R. § 1.97(e)

Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

Sir:

I hereby certify that each item of information contained in the accompanying Information Disclosure Statement was cited in a communication from a foreign patent office in a counterpart foreign application not more than three (3) months prior to the filing of this statement.

Dated this 22nd day of October, 2004.

Respectfully submitted,

Adrian J. Lee
Attorney for Applicant
Registration No. 42,785
Customer No. 022913

AJL:ds

INFORMATION DISCLOSURE CITATION (Use several sheets if necessary)	Docket Number (Optional) 15689.62	Application Number 09/750,814
	Applicant(s) Minami Ishii et al.	
	Filing Date December 28, 2000	Group Art Unit 2681

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U.S. PATENT DOCUMENTS

*EXAMINER INITIAL	REF	DOCUMENT NUMBER	DATE	NAME	CLASS	SUBCLASS	FILING DATE IF APPROPRIATE

U.S. PATENT APPLICATION PUBLICATIONS

*EXAMINER INITIAL	REF	DOCUMENT NUMBER	DATE	NAME	CLASS	SUBCLASS	FILING DATE IF APPROPRIATE

FOREIGN PATENT DOCUMENTS

	REF	DOCUMENT NUMBER	DATE	COUNTRY	CLASS	SUBCLASS	Translation YES	Translation NO
	1	EP 0 704 985 A 2	4/3/1996	Europe	H04B1	707	✓	
	2	GB 2234354 A	1/30/1991	United Kingdom	G01R 29	08	✓	
	3	2,333,723	6/11/1999	Canada	H04B17	00	✓	

OTHER DOCUMENTS *(Including Author, Title, Date, Pertinent Pages, Etc.)*

	4	Austrian Patent Office Service and Information Sector (TRF) Search report for Singapore Patent Application No.: 200007693-5

EXAMINER	DATE CONSIDERED

EXAMINER: Initial if citation considered, whether or not citation is in conformance with MPEP Section 609; Draw line through citation if not in conformance and not considered. Include copy of this form with next communication to applicant.

CERTIFICATE OF MAILING BY "EXPRESS MAIL" (37 CFR 1.10) Applicant(s): Minami Ishii et al.			Docket No. 15689.62	
Application No. 09/750,814	Filing Date December 28, 2000	Examiner Unknown	Customer No. 022913	Group Art Unit 2681
Invention: PATH TIMING DETECTING METHOD IN MOBILE COMMUNICATIONS SYSTEM AND BASE STATION				

O I P E

OCT 2 2 2004

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is being deposited with the United States Postal Service "Express Mail Post Office to Addressee" service under 37 CFR 1.10 in an envelope addressed to: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450 on

October 22, 2004
(Date)

Adrian J. Lee
(Typed or Printed Name of Person Mailing Correspondence)

(Signature of Person Mailing Correspondence)

EV 525475275 US
("Express Mail" Mailing Label Number)

Note: Each paper must have its own certificate of mailing.

Transmittal for Information Disclosure Statement (1 pages; duplicate);
Information Disclosure Statement Under 37 C.F.R. § 1.97 (2 pages);
PTO 2038 Credit Card Form for $180.00
Petition for Consideration (1 page)
Promptness Certification (1 page)
Form PTO-1449 Listing of References (1 page);
Legible Copy of References (4 references)
Certificate of Express Mail (EV 525475275 US);
Acknowledgment Postcard

(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 0 704 985 A2

(12) EUROPEAN PATENT APPLICATION

(43) Date of publication:
03.04.1996 Bulletin 1996/14

(21) Application number: 95112921.2

(22) Date of filing: 17.08.1995

(51) Int. Cl.[6]: H04B 1/707, H04B 7/005, H04B 7/02

(84) Designated Contracting States:
DE FR NL SE

(30) Priority: 28.09.1994 GB 9419496

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Romsey, Hampshire, SO51 0ZN (GB)

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Siemens Group Services Limited
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Romsey Hampshire SO51 0ZN (GB)

(54) Clock phase adjustment circuit in a RAKE receiver for spread spectrum signals

(57) For a Rake Receiver in which the received signal is sampled at only one sample per chip, the signal is energy collected from several multipath components by the Rake fingers. If any multipath component is not perfectly aligned with the sampling time, several Rake fingers will be needed to collect its energy. If the number of Rake fingers available is limited then more efficient collection of energy is possible if fine timing correction is applied to the sampling so that optimum sampling is applied to the strongest multipath component. In this way only one Rake finger is required and the other Rake fingers may be dedicated to the remaining multipath components. The present invention uses two types of control methods, a Tau dither phase control circuit or a pilot jitter clock circuit. The control circuit generates control signals for the various Rake fingers and also controls a clock phase adjuster which in turn controls a sample and hold circuit which receives the analogue complex baseband input signal which is fed via a digital to analogue converter into a complex shift register, each stage of which is connected to each Rake finger and is selectable by each Rake finger.

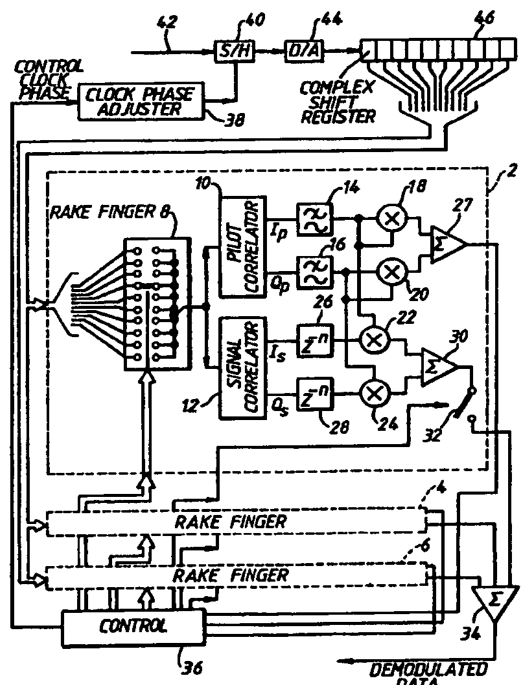

Fig. 1

EP 0 704 985 A2

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Description

The present invention relates to apparatus for use in equipment providing a digital radio link using direct sequence spread spectrum between a fixed and a mobile radio unit.

In co-pending patent application number 9316489.5, there is described a comprehensive Rake Receiver in which a contiguous set of Rake fingers is not required. The savings in cost and complexity are maximised if the fewest number of Rake fingers are used. The sampling of a received signal is performed at only one sample per chip and multiple Rake fingers are used.

The Rake fingers referred to above may be assigned to a single multipath component in order to acquire most of its energy when the component is sampled at a non optimum time. When the number of available Rake fingers is limited (eg n), these are assigned to the n strongest responses to the multipath components. If the strongest multipath component is non optimally sampled then several Rake fingers will need to be assigned to its responses in order to recover most of its power. In this case fewer Rake fingers remain available for assignment to the other multipath responses. If the timing of sampling can be held such that the strongest multipath component is always sampled optimally, then only one Rake finger will be needed for its reception. This makes available more of the other Rake fingers for combining the signal from the other multipath components, permitting improved overall performance. Conversley, for the same performance a smaller number of Rake fingers could be used.

In the context of CDMA cellular mobile radio systems, the present invention is only of benefit on the downlink (base station to mobile unit direction). The reason for this is that the base station receiver must handle signals received from many mobile units, all coming over different propagation paths so that the delays associated with the strongest path for every signal will be different. Since all signals pass through a single digital to analogue converter it is not possible to control the timing of the sampling for the different received signals independently.

For the mobile unit receiver, however, the signal is received from only one base station so that alignment is possible. The saving from this is most beneficial, because there are far more mobile unit receivers than base station receivers and because power consumption is critical.

Accordingly, an aim of the present invention is to provide apparatus in which a timing loop is closed around a single Rake finger which is experiencing the strongest signal, which is sampled at only one sample per chip thereby rendering arbitrary the timing of other Rake fingers with respect to their multipath components.

According to the present invention there is provided apparatus for use in equipment providing a digital radio link between a fixed and a mobile radio unit, said apparatus comprising a radio receiver having a plurality of Rake fingers, each Rake finger having means for selectively receiving the contents of each bit of a shift register, said shift register being arranged to receive an analogue complex baseband signal via a sample and hold circuit and a digital to analogue converter, wherein said sample and hold circuit receives a control signal from a clock phase adjuster circuit which is controlled by control means in dependence upon an output signal received from each Rake finger.

An embodiment of the present invention will now be described with a reference to the accompanying drawings wherein:

Figure 1 shows a block diagram of a single finger aligned Rake receiver,

Figure 2 shows a block diagram of the controller shown in Figure 1, and

Figure 3 shows a block diagram of an alternative controller as shown in Figure 1.

Referring to Figure 1 there is shown a basic single finger aligned Rake finger comprising three Rake fingers 2, 4, 6. It will be appreciated that each Rake finger is identical and the description hereafter refers to the Rake finger 2 only. Each Rake finger comprises a selectible switch 8 the output of which is connected to an input of a pilot correlator 10 and to an input of a signal correlator 12. Each correlator generates an inphase output signal and a quadrature phase output signal. Each output from the pilot correlator 10 is connected to a filter 14, 16 respectively, the outputs of which are connected to first and second inputs of a multiplying circuit 18, 20 respectively and to an input of multiplying circuits 22, 24 respectively. The outputs of the signal correlator 12 are each connected to an input of a delay circuit 26, 28, the output of which is connected to a further input of a respective multiplying circuit 22, 24. The outputs from the multiplying circuits 18, 20 are connected to a summator 27, and the outputs of the multipliers 22, 24 are connected to a summator 30. The output summator 30 is connected via a controlled switch 32 to a further summator 34. The output of the summator circuit 27 is connected to an input of the control circuit 36.The output from the summator 30 and of the summators in the other Rake fingers are similarly connected to an input of the summator 34, the output of which generates the demodulated data. The outputs from the summators 27 in the other Rake fingers are also connected to the input of the control circuit 36. The output of the control circuit 36 is connected to an input of a clock phase adjuster circuit 38, the output of which controls a sample and hold circuit 40 which receives at an input thereof, an analogue baseband signal on input lead 42. The output of the sample and hold circuit is connected to a digital to analogue converter 44, the output of which is connected to a first stage of a complex shift register 46. Each stage of the complex shift register 46 is connected to a respective input of the selectable switch 8 in each Rake finger.

The control circuit 36 provides a signal to control the clock phase of the sample and hold circuit 40 via the

clock phase adjuster circuit 38 to obtain optimum sampling. The control can be performed in either a digital or an analogue fashion. The funtionality of the control circuit 36 either implements a Tau dither loop (as familiar to those versed in the art) or a jittered pilot receiver as described in patent application number 9415191.7. The remainder of the circuit operation is as described in patent application number 9413268.5.

Referring to Figure 2, the control function implemented by a Tau Dither loop will now be described.

The control circuit comprises several integrators 50, 52, 54 which receive the output signals from the summators 27 in each Rake finger of Figure 1. These signals are also connected to a plurality of control switches 56, 58, 60. These switches are controlled by a largest select circuit 62 which receives the outputs from the integrator circuits 50, 52 and 54. The output of each switch 56, 58, 60 is connected to an input of an inverter 64 and to an input of a switching circuit 66 the function of which is to short circuit the inverter 64. The output of the subtractor circuit 64 is connected to a further input of the switch 66, the output of which is connected to an integrator filter 68. The output of the integrator filter 68 is connected to the input of a summator 70. The switch 66 and the further switch 72 are controlled by a dither clock generator 74. The switch 72 is arranged to switch a positive or negative offset to a further input of the summator 70, the output of which is used to control a clock phase and is applied to the clock phase adjuster 38 in Figure 1.

The integrators 50, 52, 54 average the signal power over a measured interval (several milliseconds) and the largest is selected and routed by the switches 56, 58, 60 to an inverter 64 and switch 66 which alternatively adds and subtracts the current measurement into the integrator 68. Synchronously with this operation, a Dither signal is generated and added to the output of the control signal. Operation is thus that the Dither signal causes the pilot power for the strongest Rake to be measured when the sample phase is early and when it is late. Alternate addition and subtraction of these into the integrator 68 is equivalent to feeding the difference of early and late measurements into the loop filter. When the timing is correct, the pilot signal in the early case will be the same is in the late case.

Referring to Figure 3, a pilot jitter solution is shown. In Figure 3 like elements as in Figure 2 have been given the same reference numeral and operate in the same manner. It will be noted that the difference is the provision of pilot jitter clock 76 which is used directly to control the switch 66. There is no need for a summator 70 as shown in Figure 2 or the additional switch 72 for providing a positive and negative offset. As mentioned above, there is no need for a Dither circuit since this is implemented on the pilot in the transmitter. The pilot jitter clock is synchronised to the local pilot code, dividing between the early and late phases of the pilot jitter.

It will readily be appreciated by those skilled in the art the various implementations are possible within the scope of the present invention.

Claims

1. Apparatus for use in equipment providing a digital radio link between a fixed and a mobile radio unit, said apparatus comprising a Rake receiver having a plurality of Rake fingers, each Rake finger having means for selectively receiving the contents of each bit of a shift register, said shift register being arranged to receive an analogue complex baseband signal, via a sample and hold circuit and a digital to analogue converter, wherein said sample and hold circuit receives a control signal from a clock phase adjuster circuit which is controlled by control means in dependence upon an output signal received from each Rake finger.

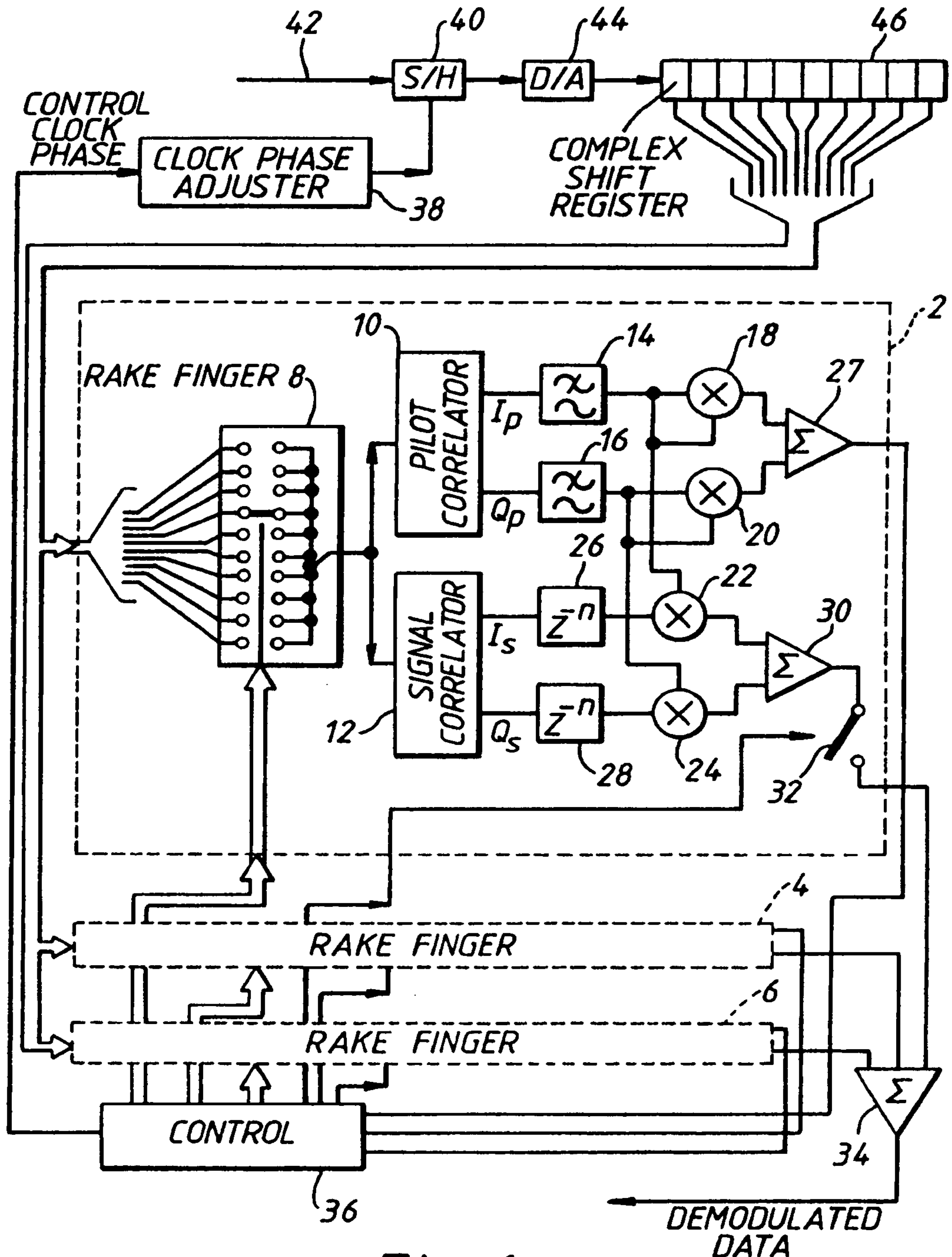
2. Apparatus as claimed in claim 1, wherein each Rake finger includes a pilot correlator from which said output signal is generated.

3. Apparatus as claimed in claim 1 or claim 2, wherein the control means is a Tau dither phase control circuit.

4. Apparatus as claimed in claim 1 or claim 2, wherein the control means is a pilot jitter phase control circuit.

5. Apparatus as claimed in claim 3, wherein the Tau dither control circuit includes integration means for averaging the signal power over an interval of time on each input line to the control means, means for selecting the largest signal, means for alternately adding and subtracting said selected signal into a further integrator, and means for adding a dither signal to the output signal of said further integrator.

6. Apparatus as claimed in claim 4, wherein the dither phase control circuit includes integration means for averaging the signal power over an interval of time on each input line to the control means, means for selecting the largest signal, and means for alternately adding and subtracting said selected signal into a further integrator under the control of a pilot jitter clock signal.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CORRELATOR
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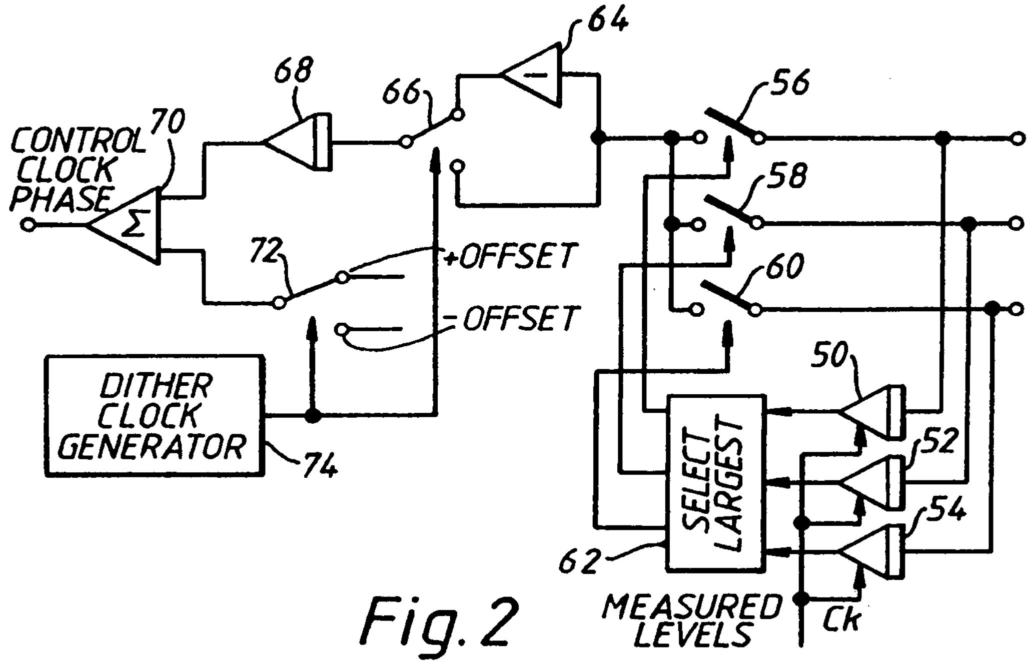
DEMODULATED
DATA

Fig. 1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CONTROL CLOCK PHASE
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52
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Fig. 2

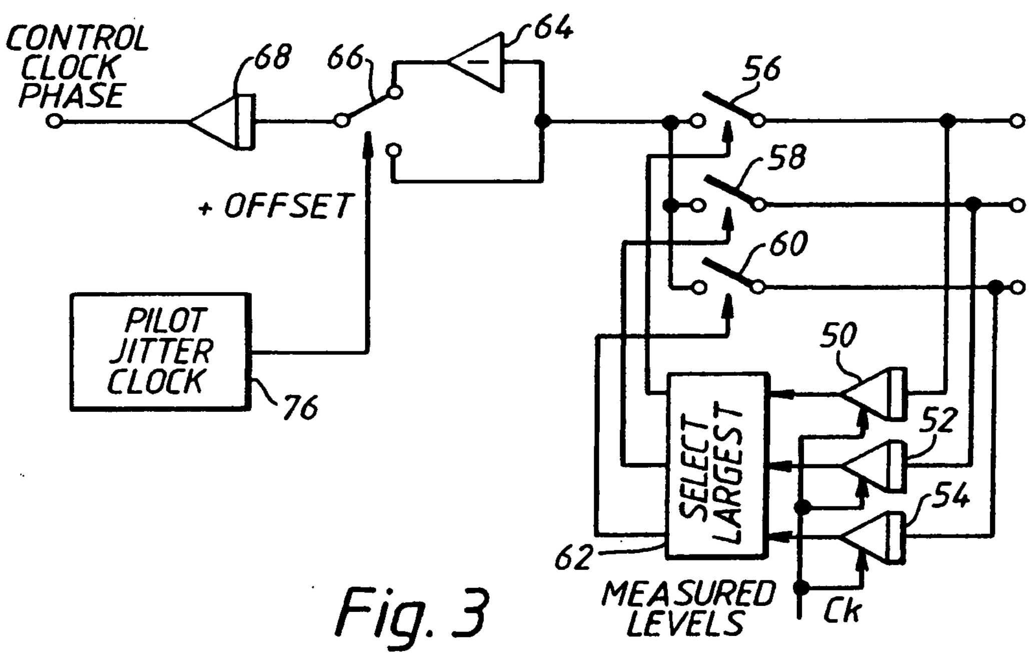
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Fig. 3

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Fax.No.: ++431/53424/520

To

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#04-01 Plaza By The Park

SINGAPORE 0718

Date of mailing: 30. Juli 2004

Applicant		
NTT DOCOMO, INC.		
Application No. 200007693-5	Filing Date 28 December 2000 (28.12.2000)	(Earliest) Priority Date 28 December 1999 (28.12.1999)
International Patent Classification (IPC^7)	H04B 1/707, 1/00, 7/14, 7/20, 7/00	

Please find enclosed the

- [x] SEARCH REPORT
- [x] EXAMINATION REPORT
- [ ] WRITTEN OPINION

provided by the Austrian Patent Office as Search and Examination Authority according to the Memorandum of Understanding between the Government of Singapore and the Austrian Patent Office (MOU)

Best regards

AUSTRIAN PATENT OFFICE Service and Information Sector TRF	Dr. Flammer

Enclosures:

- [x] the search report
  (it is also accompanied by a copy of each prior art document cited in the report)
- [x] the examination report
- [ ] the written opinion
- [ ] the Registry's copy of the priority application

Austrian Patent Office

Application No. 200007693-5	Applicant: NTT DOCOMO, INC.
Filing date 28 December 2000 (28.12.2000)	(Earliest) Priority Date 28 December 1999 (28.12.1999)

GENERAL OBSERVATIONS

☒ With regard to the abstract the text is approved as submitted by the applicant.

☒ The application contains neither statements disparaging any person nor expressions etc. contrary to morality or the public order.

☒ Unity of invention is given.
Consequently, all parts of the application were the subject of examination in establishing this report.

☒ Basis of the report:
The search report and the examination report have been drawn on the basis of the application as transmitted with the request.

☒ This report has been established in consideration of the claimed priority dated 28.12.1999.
Thus for the purposes of this report, the filing date indicated above is considered to be the relevant priority date.

☒ Further Remarks:
The following observations on the clarity of the claims, description and drawings or on the question whether the claims are fully supported by the description, are made: Although the present application comprehends claims of different categories and several independent claims of the same category it relates to one invention only.

AUSTRIAN PATENT OFFICE Dresdner Straße 87, A-1200 VIENNA Facsimile No. ++431/53424/535	Authorized Officer **BERGER R.** Telephone No. ++431/53424/ **571**

SEARCH REPORT

Application No.
200007693-5

A. CLASSIFICATION OF SUBJECT MATTER

According to the International Patent Classification (IPC^7):

H04B 1/707, 1/00, 7/14, 7/20, 7/00

B. FIELDS SEARCHED IPC^7:

H04B, H04Q, G01R

Electronic data base consulted during the search (name of data base and, where practicable, search terms used)

WPI

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	CA 2333723 A1 (ERICSSON INC.) 16 December 1999 (16.12.1999) *abstract, figs. 1-7, claims 1-21, page 1, line 12 - page 5, line 8, page 5, line 18 - line 19.* --	1-8
A	GB 2234354 A (THE MARCONI COMPANY LIMITED) 30 January 1991 (30.01.1991) *abstract, figs. 1-3, claims 1-6, page 1, line 5 - page 2, line 22.* --	1-8
A	EP 0704985 A2 (ROKE MANOR RESEARCH LIMITED) 3 April 1996 (03.04.1996) *abstract, figs. 1-3, claims 1-6, column 1, line 7 - column 2, line 8.* ----	1-8

☐ Further documents are listed in the continuation of Box C. ☒ See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the filing date but later than the priority date claimed

"T" later document published after the filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of actual completion of the search: **3 June 2004 (03.06.2004)**

AUSTRIAN PATENT OFFICE
Dresdner Straße 87, A - 1200 VIENNA
Facsimile No. ++431/53424/535

Authorized Officer **BERGER R.**

Telephone No. ++431/53424/ **571**

Austrian Patent Office

Application No. 200007693-5	Applicant **NTT DOCOMO, INC.**
Filing date 28 December 2000 (28.12.2000)	(Earliest) Priority Date 28 December 1999 (28.12.1999)

SEARCH REPORT

EXPLANATIONS

Document CA 2333723 A1 (ERICSSON INC.) shows a channel signal strength evaluation method in a spread spectrum communication system and the complex base-band signal is received and converted into a sample stream at a predetermined sampling rate by a sampler and the sample stream is again sampled by a sampler at a different sampling rate and the signal strength of the channel is measured based on the two sample streams.

Document GB 2234354 A (THE MARCONI COMPANY LIMITED) shows a method which involves a mobile station communicating with at least one base station and samples are obtained representative of the strength of the signal received at the mobile station on a channel transmitted by the base station, and processed to produce a 1st average value of signal strength from a determined number of samples.

Document EP 0704985 A2 (ROKE MANOR RESEARCH LIMITED) shows an apparatus for use in an equipment providing a digital radio link between a fixed and a mobile radio unit which has a Rake receiver with a number of Rake fingers and each finger selectively receives the contents of each bit of a shift register and the shift register receives an analogue complex base-band signal.

SEARCH REPORT

Information on patent family members

Application No.
200007693-5

This annex lists the patent family members relating to the patent documents cited in the search report.
The members are as contained in the EPIDOS INPADOC file.
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Patent document cited in search report	Publication date	Patent family member(s)	Publication date
CA A 2333723		ID A 30268	2001-11-15
		DE T 69907183T	2003-10-30
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		JP T 2002518873T	2002-06-25
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☒ EXAMINATION REPORT

☐ WRITTEN OPINION

Application No.
200007693-5

Reasoned statement with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

Date of actual completion of the report / opinion: **3 June 2004 (03.06.2004)**

1. STATEMENT

Novelty (N)	YES	Claims	1-8
	NO	Claims	----
Inventive step (IS)	YES	Claims	1-8
	NO	Claims	----
Industrial applicability (IA)	YES	Claims	1-8
	NO	Claims	----

2. CITATIONS AND EXPLANATIONS

The following documents have been cited in the Search Report:

D1: CA 2333723 A1
D2: GB 2234354 A
D3: EP 0704985 A2

Documents D1-D3 cited in the search report merely disclose the state of the art and neither directly reveal nor suggest the recited features of the present application, namely, that there is a path timing detecting method in a mobile communications system, in which when a plurality of mobile stations access a base station using a common channel at arbitrary timings, each mobile station transmits a preamble for notifying the base station of an occurrence of a message before actually transmitting the message, wherein the path timing detecting method comprises a step of identifying an effective path timing range using the preamble received by the base station and a step of detecting effective path timings in the identified path timing range using the message transmitted from the mobile station.

There is also an inventive step involved.

The industrial applicability of the features of claims 1-8 is given since the present application relates to an accurate detection of path timing and checking an increase in processing load to a great extent.

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(12) (19) (CA) **Demande-Application**

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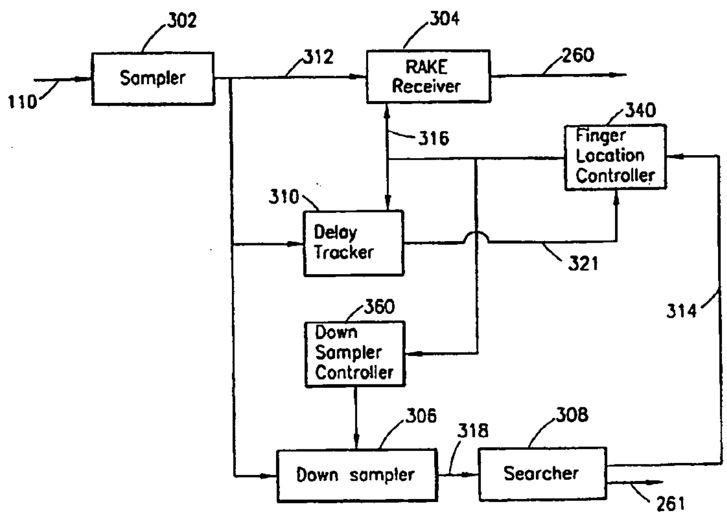
(54) **DISPOSITIF DE MESURE D'INTENSITE DE SIGNAUX PILOTE ET DE RECHERCHE DE VOIES DE PROPAGATION PAR TRAJETS MULTIPLES POUR RECEPTEUR AMCR**

(54) **PILOT STRENGTH MEASUREMENT AND MULTIPATH DELAY SEARCHER FOR CDMA RECEIVER**



(57) L'invention se rapporte à un procédé et à un appareil permettant d'évaluer l'intensité des signaux d'un canal reçu au niveau d'une station mobile au sein d'un système de communication à étalement des spectres. Si le récepteur de la station mobile reçoit un signal à spectre étalé, un premier dispositif d'échantillonnage convertit ce signal en un premier train d'échantillonnage, à une première fréquence d'échantillonnage. Un second dispositif d'échantillonnage convertit le premier train d'échantillonnage en un second train d'échantillonnage à une seconde fréquence d'échantillonnage, différente de la première fréquence d'échantillonnage. L'intensité du signal d'un canal pour signaux pilotes est mesurée en fonction des premier et second trains d'échantillonnage.

(57) A method and apparatus for evaluating signal strength of a channel received at a mobile station within a spread spectrum communication systems is disclosed. If the receiver at the mobile station receives a spread spectrum signal, a first sampling means converts the received signal into a first sample stream as a first sampling. A second sampling means converts the first sample stream into a second sample stream at a second sample rate, different from the first sample rate. The signal strength of a pilot channel is measured based upon the first and second sample streams.

Industrie Canada Industry Canada

ABSTRACT OF THE INVENTION

A method and apparatus for evaluating signal strength of a channel received at a mobile station within a spread spectrum communication systems is disclosed. If the receiver at the mobile station receives a spread spectrum signal, a first sampling means converts the received signal into a first sample stream as a first sampling. A second sampling means converts the first sample stream into a second sample stream at a second sample rate, different from the first sample rate. The signal strength of a pilot channel is measured based upon the first and second sample streams.

PILOT STRENGTH MEASUREMENT AND MULTIPATH DELAY SEARCHER FOR CDMA RECEIVER

BACKGROUND OF THE INVENTION

Technical Field of the Invention

The present invention relates to transmission of telecommunications data in a cellular communication system using spread spectrum modulation and, more particularly, to a method and apparatus for measuring pilot signal strengths and finding multipath delays for Code Division Multiple Access channels in a cellular communication system.

Description of Related Art

Spread spectrum communication technology has been used in military communications since the days of World War II, primarily for two purposes: to overcome the effects of strong intentional interference on a certain frequency and to protect the signal from unauthorized access. Both these goals can be achieved by "spreading" the signal spectrum to make it virtually indistinguishable from background noise, hence the term spread spectrum modulation.

Code Division Multiple Access, or CDMA, is a digital cellular spread spectrum multiple access method. In known CDMA systems, a number of base stations are typically located within a service area. Each base station uses one or more CDMA channels to communicate with one or more mobile stations located within the same service area. The base-to-mobile station transmission direction is known as the forward link or downlink and the mobile-to-base station direction is known as the reverse link or uplink.

In a CDMA system, an information data stream to be transmitted is modulated by a data sequence with a much higher data rate, referred to as a "signature sequence". Each element of the signature sequence typically represents one binary logical symbol ("0" or "1"). The signature sequence usually comprises N bits, wherein each of the N bits is denoted as a "chip". One way to generate such a signature sequence is by using a periodic binary sequence of pseudorandom signals to modulate a periodic impulse stream of period T_c, also referred to as "chip duration". The sequence of

pseudorandom signals is also known as a pseudo noise (PN) sequence, so called because it appears random but can be replicated by an authorized receiver.

The information data stream and the high bit rate signature sequence are combined by first mapping the binary logical signals ("0" or "1") to real values ("+1" or "-1"), and multiplying the two bit streams together. The combination of the lower bit rate information data stream with the higher bit rate signature sequence creates a noiselike wideband signal. This technique is called "coding" or "spreading" the information data stream and is well known in the art.

In traditional cellular communication systems, co-channel interference between channels due to spectrum reuse is one of the main limiting factors in achieving a high system capacity. One of the most notable features of CDMA technology is universal frequency reuse, which means that all users within a CDMA system occupy a common frequency spectrum allocation. This is accomplished by allocating different codes to different channels. On the downlink, each base station transmits a unique, unmodulated spreading code, denoted pilot code, pilot channel or "pilot". The pilot generally consists of a sequence of chips, each having a chip duration T_c. Each pilot is a different shift of a common complex sequence. Hence, on the forward link, each base station transmits a unique, unmodulated pilot channel, and may additionally transmit a synchronization channel, paging channels and traffic channels. The term "CDMA channel set" is used to refer to a set of channels transmitted by a base station.

Each mobile station in a CDMA system searches for pilot codes to detect the presence of base station signals and to measure their strengths. For purposes of this disclosure, a forward CDMA channel set containing one or more traffic channels assigned to the mobile station is referred to as an "active channel", and the pilot signal of such an active channel is referred to as an "active pilot". Conversely, a CDMA channel set which contains no traffic channels assigned to the mobile station is referred to as a "non-active channel", and the pilot signal of such a non-active channel is referred to as a "non-active pilot". Since no traffic information is transmitted from the base station to the mobile station on the non-active channels, there is no need for demodulating these channels. Thus, the mobile station must only be able to demodulate the active CDMA channel sets.

A well-known source of degradation common to all known wireless multiple access systems, particularly in terrestrial environments, is known as "multipath

fading". In a multipath environment, the transmitted signal follows several propagation paths from a transmitter to a receiver, typically as a result of the signal reflecting off one or more objects before arriving at the receiver. Since the various propagation paths of the transmitted signal are of unequal lengths, several copies of the transmitted signal will arrive at the receiver with varying time delays. In a multipath fading channel, phase interference between different propagation paths of the transmitted signal may cause severe fading and result in signal dropout or cancellation.

A mobile station in a CDMA system is typically equipped with a receiver for demodulating active channels and compensating for multipath delays as described above. The receiver is generally denoted a RAKE receiver since it "rakes" all the multipath contributions together. A RAKE receiver consists of a number of processing units or RAKE fingers. When demodulating a multipath fading channel, each finger of the RAKE receiver must be synchronized with one of the diverse propagation paths of the channel. A RAKE receiver comprising L fingers is able to detect, at most, L copies of the transmitted signal. which are corrected for time delays and added coherently, (co-phased and scaled). The resulting signal will thus comprise a collection of all the time delayed copies of the transmitted signal.

As previously described, due to multipath propagation the transmitted signals will arrive at different times at the mobile station and hence result in a number of time delayed copies of the transmitted signal at the receiver. The relative time delays of the received copies of the transmitted signal must be determined in order to synchronize the various propagation paths of the signals with the corresponding fingers of the RAKE receiver. Unfortunately, the number and magnitude of the time delays may change due to movement of the mobile station, i.e., variable distance and velocity relative to the transmitting base station for users in motion. Also, movement of the mobile station may cause new channel paths to appear and old channel paths to disappear. Hence, the mobile station must continuously monitor the signals received along all propagation paths of an active channel in order to search for new. stronger channel paths. To perform this monitoring efficiently, the multipath time delays must be substantially continually measured or estimated in a fast and accurate manner.

In a cellular system conforming to the TIA/EIA/IS-95 "Mobile station - base station compatibility standard for dual mode wideband spread spectrum cellular

system" standard, the ANSI J-STD-008 "Personal station - base station compatibility requirements for 1.8 to 2.0 GHz code division multiple access (CDMA) personal communications systems" standard, or other similar standards, a mobile station must be able to switch connection from a first base station to a second base station if the second base station provides a stronger signal to the mobile station, a procedure known as "handoff". As described in the standards documentation, the handoff may be accomplished through either a "hard" handoff or a "soft" handoff.

In hard, or traditional, handoff, the connections to different base stations use different frequencies, which means that the connection to the old base station is broken before the connection to the new base station is set up. However, because of the universal frequency reuse in a CDMA system, it is possible to set up the connection to a new base station before leaving the old base station, a procedure known as soft handoff. According to the above-identified standards, the mobile station must continuously measure the signal strengths for all received pilots in order to decide if a handoff, either hard or soft, is required.

Both of the two functions just described, i.e., searching for stronger paths for active channels using time delay estimates and continuously measuring pilot signal strengths for received channels, are typically performed by a circuit in the mobile station generally denoted a "searcher". The searcher specifies a window of correlation, also referred to as a search window, for each received pilot signal. The search window consists of a predetermined number of consecutive chips among which the probability of finding usable multipath components of the corresponding channel is high. To specify the search window for a particular pilot, a locally generated replica (local pilot) of that particular pilot is used for correlation with the received pilot. The search window is centered around the earliest arriving usable multipath component (correlation peak) of the pilot, which occurs when the received pilot matches the locally generated pilot. The search window further employs a search range of W chips on either side of the center, where W is a predefined number as specified in either of the standards TIA/EIA/IS-95 or ANSI J-STD-008 as referred to above.

The conventional technique for performing the correlation described above is by using an "integrate and dump" correlator, which integrates the received signals during a given time period and then resets itself. The correlation peaks for each search window are detected, and the results are used to calculate the pilot strength for the

corresponding pilots. Also, the estimated multipath delays for the active channels to be demodulated are calculated based on the correlation results. These estimated multipath delays are used to synchronize each finger of the RAKE receiver with one of the propagation paths of the active channels as previously described.

Prior searcher techniques typically employ integrate and dump correlation for each separate multipath delay in each search window. Such a method is calculation intensive which makes the search process relatively slow. Consequently, valuable time which could be used to improve the accuracy of the search results is wasted.

Accordingly, there is a need in the art for an improved method and apparatus for searching for stronger paths for active CDMA channels while continuously measuring pilot signal strengths for all received CDMA channels. The present invention uses new techniques to generate and process a search window for each pilot in the system, resulting in faster and more accurate measurements.

SUMMARY OF THE INVENTION

The present invention overcomes the foregoing and other problems, with a method and apparatus for evaluating the signal strength of a CDMA channel received at a mobile station in a spread spectrum communication system. The receiver at the mobile station receives a pilot signal for the channel being evaluated. The pilot signal is converted at a first sampling means into a first sample stream having a first sampling rate. The first sample stream is next converted at a second sampling means into a second sample stream having a second sampling rate that is different from the first sampling rate. The signal strength of the channel is measured based upon the first and second sample streams.

The process of measuring the signal strength of the channel involves generating, with a sliding correlator, a search window for the first sample stream by multiplying a local section of the pilot signal with a second section of the pilot signal in order to obtain a sequence of correlated values, and centering the search window around the earliest detected correlation peak of the correlation values. The signal strength of the second sample stream is measured using the search window. The generated search window may even be averaged using previously generated search windows for the pilot signal and may improve the generated samples of the search

window with a smoothing factor using previously generated samples for the pilot signal.

BRIEF DESCRIPTION OF THE DRAWINGS

For a more complete understanding of the present invention, reference is made to the following detailed description taken in conjunction with the accompanying drawings wherein:

FIGURE 1 shows a conventional CDMA receiver;

FIGURE 2 shows a baseband processor for processing a complex baseband signal in the CDMA receiver shown in FIGURE 1;

FIGURE 3 shows a baseband processor for processing an active pilot channel in accordance with the present invention;

FIGURE 4 shows a baseband processor for processing a non-active pilot channel in accordance with the present invention;

FIGURE 5 shows a sliding correlator with complex square law envelope output for measuring pilot signal strength in accordance with the present invention;

FIGURE 6 is a flowchart showing the function of a searcher in accordance with the present invention; and

FIGURE 7 shows an example of a combination of a plurality of search windows for a corresponding plurality of pilot signals.

DETAILED DESCRIPTION OF THE INVENTION

Referring now to the drawings, and more particularly to FIGURE 1, wherein there is illustrated a simplified block diagram of a conventional CDMA receiver 100. A pilot signal 108 is received by an antenna 102 and converted in a RF section 104 into a complex baseband signal 110 which is comprised of a "real" or in-phase component and an "imaginary" or quadrature-phase component. According to the IS-95 standard, all pilot signals in a CDMA system must have a chip waveform which follows approximately a Sinc function which is defined as $\mathrm{Sinc}(y) = (\sin y)/y$. In particular, the chip waveform is approximately $\mathrm{Sinc}(\pi t/T_c)$. Consequently, the chip waveform of the complex baseband signal 110 will also approximately follow a Sinc function. The complex baseband signal 110 is fed to a baseband processor 106 for further processing as described below.

FIGURE 2 shows an internal configuration of the baseband processor 106 of FIGURE 1. The received signal 110 is encoded by demod unit 250, which produces soft bit values 260 and pilot strength measurements 261. Soft valves 260 are further processed at decoder 270, which performs forward error correction decoding and error detection to produce processed bits 280. Alternatively, demod unit 250 may produce only hard bits rather than soft bits 260 and pilot strength measurements 261.

The present invention relates to the demod unit 250 in FIGURE 2. A demod unit 250 according to the present invention is illustrated in FIGURE 3. The complex baseband signal 110 is fed into a sampler 302 which samples the baseband signal 110 at a specified rate and generates a sample stream 312. The baseband signal 110 can be sampled, for example, at eight times per chip. The sample stream 312 is provided to a RAKE receiver 304 for data detection, as well as to a delay tracker 310 and a down sampler 306. The down sampler 306 provides decimated samples to searcher 308. The searcher 308 performs signal strength measurements on the received signal. Also, the searcher 308 provides measurements to finger location controller 340, as does delay tracker 310. Finger location controller 340 estimates multipath delays for the active channels to be demodulated. Multipath delay estimates 316 are fed by finger location controller 340 to delay tracker 310 and RAKE receiver 304. The RAKE receiver 304 uses the adjusted delay estimates 316 to optimally assign samples of the sample stream 312 to each of the corresponding fingers.

The delay tracker 310 of FIGURE 3 also monitors the delay estimates 316 to adjust for variations in distance and velocity relative to the transmitter, a process generally known as "tracking". After feeding the delay measurements 321 to the finger location controller 340, the delay tracker 310 continues to track the delays. A method to improve and track delay estimates with delay tracker 310 is described in an article entitled "A new tracking loop for direct sequence spread spectrum systems on frequency selective fading channels", IEEE Trans. on Comm., Vol. 43, No. 12, December 1995 by W. Sheen and G. Stuber, the disclosure of which is hereby incorporated by reference.

In accordance with one aspect of the present invention, the complex baseband signal 110 of FIGURE 1 is sampled not once but twice per chip, using the down sampler 306 in FIGURE 3. The down sampler 306 samples the sample signal 312 at a rate lower than the sampling rate of the sampler 302, resulting in a decimated sample

signal 318 being fed to the searcher 308. This process is generally referred to as "down sampling". As those skilled in the art will readily appreciate, down sampling the sample signal 312 may advantageously result in a reduction in the hardware complexity of the searcher 308.

However, when measuring the signal strength of a sampled pilot signal, it is advantageous if one of the samples is positioned at the peak of the chip waveform, i.e., at the peak of the Sinc function. For purposes of illustration, the sampled signal 312 has a sample rate of eight samples per chip, and the decimated sample signal 318 has a sample rate of two samples per chip. With a sampling rate of eight samples per chip, it may be assumed with a high probability that one of the eight samples will be situated at or near the peak of the chip waveform. However, when down sampling the signal from eight samples per chip to two samples per chip, as described above, the probability that one of the two samples will be positioned at the peak of the chip waveform is dramatically reduced. Hence, the two samples per chip of the decimated sample signal 318 should be chosen in such a way that one of the two samples will likely be at the peak of the chip waveform of the corresponding pilot. This type of down sampling is referred to as "optimum down sampling". Additionally, the position of the first sample to be down sampled is referred to as down sampling phase.

In accordance with one aspect of the present invention, a method for selecting a down sampling phase will now be described with respect to both active pilots and non-active pilots. It should be understood that the structure, control and arrangement of the conventional components and circuits have, for the most part, been illustrated in the drawings by readily understandable block representations and schematic diagrams, which show only those specific details that are pertinent to the present invention. These block representations and schematic diagrams have been employed in order not to obscure the disclosure with structural details which will be readily apparent to those skilled in the art having the benefit of the description herein.

Referring back to FIGURE 3, the complex baseband signal 110 is fed to a sampler 302, which samples the baseband signal 110 at a specified rate. For purpose of description, it is assumed that the baseband signal 110 is sampled at a rate of eight samples per chip. The sample stream 312 is provided to the RAKE receiver 304, the delay tracker 310 and the down sampler 306 in accordance with the present invention. Each sample in a group of eight samples per chip being fed into the down sampler 306

is denoted s_i^j, where i is a chip number and j is a sample number within a chip having a value of 1 to 8. The samples in the sample signal 312 are received by the down sampler 306 in the following order:

$$\ldots\ldots, s_1^i, s_i^2, s_i^3, \ldots\ldots s_i^8, s_{i+1}^1, s_{i+1}^2, \ldots\ldots s_{i+1}^8, s_{i+1}^2, \ldots\ldots$$

We now assume that sample s_i^l is taken at the peak of the waveform of chip i for the sample signal 312. When down sampling the sample signal 312 at eight samples per chip to the decimated sample signal 318 at two samples per chip, the decimated sample signal 318 will comprise every fourth sample of the sample signal 312. Hence, after down sampling the sample signal 312 as described, the decimated sample signal 318 will for each chip consist of the two samples s_i^j and s_i^{j+4} where j denotes the down sampling phase or position.

In accordance with one aspect of the present invention, the complex baseband signal 110 is associated with an active CDMA channel. In addition to measuring the pilot strength of the received signal by using correlation techniques, the searcher 308 will calculate the estimated multipath delays for the decimated sample signal 318, based on correlation results. The searcher 308 provides the finger location controller 340 with multipath delay estimates 314 for the decimated sample signal 318. The finger location controller 340 will maintain, at most, a number L of delay estimates 316 where the number L is the number of fingers in the RAKE receiver 304. For purpose of illustration, it is assumed that the delay tracker 310 tracks L active channels. Since the down sampler 306 down samples the sample signal 312 twice per chip, the accuracy of the delay estimates 314 is limited to within a half of a chip duration, or $T_c/2$. The delay tracker 310 improves the accuracy of the delay estimates 316 using known mathematical methods as described in "A new tracking loop for direct sequence spread spectrum systems on frequency selective fading channels", IEEE Trans. on Comm., Vol. 43, No. 12, December 1995 by W. Sheen and G. Stuber, and feeds new, more accurate delay estimates 321 to the finger location controller 390. In accordance with one aspect of the present invention, the finger location controller 340 also provides the down sampler controller 360 with the down sampling phase of the strongest channel path being tracked by the delay tracker 310. In accordance with another aspect of the present invention, the finger location controller 340 provides the

down sampler controller 360 with the down sampling phase of the first channel path being tracked by the delay tracker 310. Hence, in accordance with the present invention, the searcher 308 will provide the finger location controller 340 with increasingly accurate estimates of the channel delays for active channels.

In accordance with another aspect of the present invention, as illustrated in FIGURE 4, the complex baseband signal 110 is associated with a non-active CDMA channel. Since no traffic information is transmitted on a non-active channel, there is no need for demodulating the baseband signal 110. Consequently, no multipath delay estimation is performed by the searcher 308 for non-active channels. As illustrated in FIGURE 4, the complex baseband signal 110 associated with a non-active CDMA channel is sampled by the sampler 302 and down sampled by the down sampler 306 as previously described. Since the method for searching for optimum down sampling phases for active pilots as illustrated by FIGURE 3 involves the delay tracker 310, this method is not applicable for non-active pilots. Hence, the optimum down sampling phases are not known for pilots of non-active CDMA channels. If the searcher 308 was to use an arbitrary sampling position of the non-active pilot, it may result in an unknown error when measuring the signal strength of the non-active pilot.

To reduce the error in accordance with one aspect of the present invention, the down sampling phase is changed sequentially over a number of consecutive samples when measuring non-active channels. When initially receiving a particular pilot of a non-active channel, the down sampler 306 may down sample the received sample stream 312 at samples s_i^j *and* s_i^{j+4} where i is a chip number and j is an arbitrary sample number as previously described. For purpose of illustration, the down sampling phase may be changed sequentially over four consecutive samples. At subsequent search windows for the same pilot, the down sampling phase is changed sequentially to j+1, j+2, j+3, j, j+1, j+2, etc.

When using various down sampling phases for subsequent search windows, measuring the signal strength of one particular pilot, the resulting error is the average of all errors due to all possible down sampling phases. With down sampling from eight to two samples per chip, there are four possible down sampling phases. For a Sinc chip waveform, the average error, using known mathematical methods, can be calculated using the formula:

$$\text{average error} = 0.250 \sum_{j=1}^{4} 10 \log Sinc^2 (\pi(j-1)/8)$$

which yields -0.34 dB. Hence, with sequential down sampling in accordance with the present invention, the average error becomes a known factor, and the offset value, in this case 0.34 dB, can be added to the resulting signal strength of non-active pilots. This avoids the problem of an unknown error due to non-optimum down sampling of non-active channels. As will be discussed more fully below, the offset value is added to the pilot signal strength in an offset error compensation block 402 of FIGURE 4.

Once the optimum down sampling phases are chosen, a search window must be specified for each particular pilot. This is accomplished by locally generating a replica of the particular pilot for correlation with the received pilot. In accordance with one aspect of the invention, a sliding correlator is used for performing the correlation. FIGURE 5 shows a block diagram of a conventional complex sliding correlator 500 which is located in block 308 of FIGURE 3. The sliding correlator 500 has correlating units 502a, 502b, 502c and 502d for correlating the real and imaginary components of the decimated sample signal 318, and two summers 510. Corresponding squaring devices 504a and 504b square the respective added outputs of the correlating units 502a and 502d and the correlating units 502b and 502c.

Each correlating unit 502a, 502b, 502c and 502d comprises delay taps 506, multiplying taps 508 and a summer 512. The decimated sample signal 318 is provided to the delay taps 506. The series of delay taps 506 effectively functions as a first-in-first-out (FIFO) register, or queue. Since there are two samples per chip, the sample values move from one delay tap to the next delay tap at twice the chip rate. The sample values present in the delay taps 506 are provided to the multiplying taps 508, where they are multiplied by tap coefficients corresponding to samples of a particular section of the pilot code. Each of the particular sections of pilot code are denoted as a local section. For example, the number of multiplying taps 508 shown in FIGURE 5 is 128, denoted C_i to C_{i+127}, which in combination constitute one local section. To reduce complexity, it is preferred to use the flexible sliding correlator described in co-pending application U.S. Serial No. 08/829,204, "Flexible Sliding

Correlator for Direct Sequence Spread Spectrum Systems", Attorney Docket No. 27575-087.

In accordance with one aspect of the present invention, the searcher 308 comprises a sliding correlator that can be sequentially loaded with an arbitrary local section of the received pilot code. The purpose of the sliding correlator is to perform correlation for any pilot in the system. Also, a section of randomly chosen chips, not corresponding to any pilot in the system, can be loaded into the sliding correlator to measure total received spectral density I_0, if necessary. FIGURE 6 is a flowchart 600 describing the function of the searcher 308 in greater detail.

For purpose of illustration, it can be assumed that each mobile station in the CDMA system has a list of pilots to measure. It is also assumed that the pilot to be measured is pilot number n on the list of all pilots to be measured for a particular mobile station and that the search window size is W chips. As illustrated in FIGURE 6, a local section of pilot number n is generated and stored in a memory in step 602. In step 604, the local section of the pilot is fed into the multiplying taps of the sliding correlator. Preferably, the local section is loaded into the sliding correlator at least $WT_c/2$ seconds before pilot number n is going to correlate.

To generate a search window for a particular pilot. the received signal is loaded into the delay taps of the sliding correlator in step 606. Samples may be constantly loaded all the time, or loading may be turned on and off to save power. At the output of the sliding correlator, 2*W+1 output samples are collected and stored in a memory in step 608. The output samples are denoted $u^n(m)$, where n is the pilot number as described above and m corresponds to a particular delay from the peak correlation in the search window and has a value in the range -W to W. As will be apparent to those skilled in the art, $u^n(m)$ is thus the sliding correlator output due to pilot number n with a delay of m samples (m/2 chips) from the peak correlation. A delay of m = 0 would indicate that the received samples match the local section in the sliding correlator.

Based on the correlation results. search windows for the particular pilot are generated and stored in memory in step 610. After using local sections of a first pilot to correlate with the first pilot, local sections of a second pilot are loaded into the sliding correlator for correlation with the second pilot. The local sections may be replaced by a random sections, comprising a sequence of randomly chosen chips, which are loaded into the correlator to generate windows of total received spectral

density I_0 measurements. The search windows for each pilot, and the windows of I_0 measurements, are processed as described below.

Output samples corresponding to a search windows for a single pilot are averaged with previous search windows of the same pilot in step 612. The process returns to step 602 of FIGURE 6, where a new local section corresponding to the next pilot is loaded into the correlator. Generating and averaging search windows for the same pilot may be performed an arbitrary number of times. For purpose of illustration, the process for a particular pilot is performed V times for this example V = 2 (FIGURE 7).

Thereafter, a local section of a new, second pilot is loaded into the multiplying taps of the sliding correlator. The new local section corresponds to the second pilot to be measured. This process may be repeated V times. The output samples from the sliding correlator corresponding to the search window of the second pilot are also collected, averaged and stored in step 612. This process continues until all pilots on the list are measured, and the corresponding search windows are generated and stored. A random local section is also loaded and the sliding correlator samples are averaged. The cycle is repeated continuously, i.e., the first pilot window is measured again, and so on.

In step 614, output samples from the sliding correlator corresponding to pilot number n having identical delay estimates are continuously smoothed by a smoothing factor p. Hence, whenever a new averaged search window for the same pilot is measured, the "old" samples are smoothed with the "new" samples using the formula:

$$u^n_{smooth}(m) = p*u^n_{old}(m) + (1-p)*u^n_{new}(m)$$

where, as previously described, $u^n_{old}(m)$ is the "old" output sample for pilot number n with a delay of m samples (m/2 chips), $u^n_{new}(m)$ is the corresponding "new" sample and p is the smoothing factor. This smoothing applies also to the window resulting from the random local section. Hence, at any time there is stored in memory averaged and smoothed windows due to the outputs $u^n(m)$ from the sliding correlator for each pilot and an averaged and smoothed window due to the random local section. In a preferred embodiment, the smoothing factors are approximately p=0.99 or p=0.96.

For purposes of illustration, FIGURE 7 shows an example with three pilots and a search window having a duration of seven samples (W = 3). Two search windows for each pilot are averaged (V = 2) and smoothed in accordance with the present invention. In FIGURE 7, we assume that there are three pilots (#1,#2,#3) and that measurements of the total received power spectral density (i_o) will be performed. The search window size is further assumed to be W = 3 chips and that two search windows for the same pilot will be averaged (V = 2). A local section corresponding to pilot #1 is loaded into the complex sliding coorelator 500 to generate the first search window for pilot #1. This search window is stored as indicated at step 610. Another section corresponding to pilot #1 is located into the complex sliding coorelator 500 to generate the second search window for pilot #1. The second search window is averaged sample by sample with the previous search window for pilot #1 during step 612. Since V = 2 only two search windows are averaged.

Similarly, two other sections are used to generate two successive search windows for pilot #2. These two search windows are also averaged. The same process is repeated for pilot #3 and two other random sections. The same procedure is continuously repeated and the output samples 701 (before averaging) and 702 (after averaging) are generated. Search windows corresponding to the same pilot are smoothed according to the smoothing formula discussed previously with smoothing factor P. Thus, one search window for each pilot is generated along with one search window for the random sections.

In accordance with another aspect of the present invention, the smoothing factor p is set equal to Ø to disable smoothing. As those skilled in the art will readily appreciate, setting the smoothing factor p equal to Ø may advantageously result in a reduction in the memory storage required for implementing the invention. In this case, the search window is fully analyzed once the results of one pilot are averaged. After the results of one pilot are averaged, the search window corresponding to this pilot is deleted from memory and hence the memory is used for the next pilot.

After averaging and smoothing of windows, in step 616 L channel paths are selected using the peaks of the search window for each pilot. For active channels, these peaks are fed to the finger location controller 340 in step 620. Also, for all pilots the peaks are also used for pilot strength measurement as described below. Hence, the L

strongest sample values for all search windows are used for pilot strength measurement in step 624. This procedure will now be described in greater detail.

For the purpose of illustration, signal strength of a pilot is denoted by u. The signal strength u of a pilot is measured by computing the ratio of the received pilot energy per chip E_c to the total received spectral density I for at most L usable multipath components. These ratios for each multipath component are then added. Hence, the signal strength u of a pilot is given by the equation:

$$u = pilot\ strength = 1/I_o \sum_{l=1}^{L} E_{c,l}$$

where $E_{c,l}$ represents the power spectral density due to pilot channel path number l.

In one aspect of the invention, the total received spectral density I_0 is found by averaging all samples in the search window generated by the random local section. This is accomplished by adding window samples and dividing by the total number of samples in step 622. In another aspect of the invention, I_0 does not need to be measured, as automatic gain control (AGC) is present, which normalizes the received samples. In this case, I_0 is known and can be easily mapped into units corresponding to the $E_{c,l}$ measurements.

To measure the signal strength u of the pilot, the averaged and smoothed output samples $u^n_{smooth}(m)$ from the sliding correlator, i.e., the averaged and smoothed search windows which are stored in memory, are used. To generate signal strength u measurement for a particular pilot, such as pilot number n, the strongest L samples of all $u^n_{smooth}(m)$ are found. The signal strength for each of these samples is denoted P_l, where l is a path number having a value between 1 and L. These samples correspond to the strongest channel paths. Since the sample delay estimates have an accuracy limited to within a half of a chip duration, or $T_c/2$, the samples are selected at least a chip away from each other, i.e. non-consecutive samples.

The signal strength values P_l must be normalized by the effect of all other CDMA channels. To normalize the pilot strength due only to pilot n, step 626 is performed in the following way. The measured value of the total received power spectral density I_0 and the L measured signal strength values P_l are supplied to block 626. The total received power spectral density I_0 can be modeled as:

$$I_o = E_{c,l} + \xi_l$$

where ξ_l represents the total received power spectral densities, excluding the pilot channel path number l being measured. It should be noted that the total received power spectral density I_0 is not a function of the path number l. When the sliding correlator is in match with a path of one pilot, each output peak $\{P_l\}$, after being averaged and smoothed over many measurements, is modeled as:

$$P_l = M \cdot E_{c,l} + \xi_l$$

where M is the length of the sliding correlator in chips. For purpose of illustration, M is set equal to 128 in FIGURE 5. Combining the three equations above, the estimated pilot strength after removing interference is given by:

$$u = \frac{1}{(m-1) I_o} \sum_{l=1}^{L} (P_l - I_o)$$

The estimated signal strength u of the pilot is fed to block 402. For all non-active pilots, an offset value is added. For purpose of illustration, an offset of 0.34 dB is added (assuming a Sinc chip waveform) in accordance with FIGURE 4. As previously described, this offset is the result of changing the sampling position sequentially when generating the search window for the non-active pilots. For pilot strength of active pilots, the signal strength values received from step 626 are left unchanged.

Although a preferred embodiment of the method and apparatus of the present invention has been illustrated in the accompanying Drawings and described in the foregoing Detailed Description, it is understood that the invention is not limited to the embodiment disclosed, but is capable of numerous rearrangements, modifications, and substitutions without departing from the invention as set forth and defined by the following claims.

WHAT IS CLAIMED IS:

1. A method for evaluating a channel's signal strength at a mobile station comprising the steps of:

receiving a spread spectrum signal;

converting the received spread spectrum signal into a first sample stream according to a first sampling rate;

converting the first sample stream into a second sample stream according to a second sampling rate, wherein the second sampling rate is lower than the first sampling rate; and

measuring a signal strength of the channel based on the first and second sample streams.

2. The method of claim 1, wherein the step of measuring comprises the steps of:

generating a search window for the second sample stream using a sliding correlator; and

measuring a signal strength of the second sample stream using the search window.

3. The method of claim 2, wherein the step of generating includes the steps of:

feeding an arbitrary local section of the signal of the channel into a delay part of the sliding correlator;

feeding a section of the received signal into a multiplying part of the sliding correlator; and

multiplying the sections sequentially with each other to obtain a sequence of correlation values.

4. The method of claim 3, wherein the step of generating further comprises the steps of:

averaging the search window using previously generated search windows for the pilot signal; and

smoothing the generated samples of the search window with a smoothing factor using previously generated samples.

5. The method of claim 4, wherein the smoothing factor is approximately 0.96.

6. The method of claim 4, wherein the smoothing factor is approximately 0.99.

7. The method of claim 1, wherein the step of converting the received signal further comprises the step of:

selecting an optimal down sampling phase for the second sample stream.

8. The method of claim 7, wherein the step of selecting comprises the step of:

extracting the optimal down sampling phase from a tracking unit which has been tracking the pilot signal.

9. The method of claim 7, wherein the step of selecting comprises the step of:

selecting an arbitrary sampling phase which is changed sequentially for each measurement.

10. The method of claim 9, wherein the arbitrary sampling phase is changed sequentially over four consecutive sampling phases.

11. The method of claim 1, wherein the second sampling rate is lower than the first sampling rate.

12. The method of claim 1, wherein the step of converting the first sample stream comprises the step of:

sampling the first sample stream at a rate of two samples per chip.

13. An apparatus for evaluating CDMA channel signal strength at a mobile station in a spread spectrum communications system, comprising:

a receiver for receiving a signal (110);

first sampling means (302) for converting the received signal (110) into a first sample stream (312) according to a first sampling rate;

second sampling means (306) for converting the first sample stream (312) into a second sample stream (318) according to a second sampling rate, wherein the second sampling rate is lower than the first sampling rate; and

a strength circuit (308) for measuring signal strength of the channel based on the first and second sample streams.

14. The apparatus of claim 13 wherein the strength circuit comprises:

a sliding correlator (500) for generating a search window for the first sample stream; and

a measurer for measuring the signal strength of the second sample stream using the search window.

15. A method for evaluating CDMA channel signal strength at a mobile station comprising the steps of:

receiving a CDMA signal;

converting the received signal into a first sample stream according to a first sampling rate;

converting the first sample stream into a second sample stream according to a second sampling rate, wherein the second sampling rate is lower than the first sampling rate;

selecting an optimal down sampling phase for the second sample stream;

generating a search window for the second sample stream using a sliding correlator;

measuring the signal strength of the second sample stream using the search window.

16. The method of claim 15, wherein the step of generating includes the steps of:

feeding an arbitrary local section of the pilot signal into a delay part of the sliding correlator;

feeding the received signal into a multiplying part of the sliding correlator; and

multiplying the sections sequentially with each other to obtain a sequence of correlated values.

17. The method of Claim 16 further including the step of:

centering a search window around the earliest detected correlation peak among the correlation values.

18. The method of claim 16, wherein the step of generating further comprises the steps of:

averaging the search window using previously generated search windows for the CDMA channel signal; and

smoothing the generated samples of the search window with a smoothing factor.

19. The method of claim 15, wherein the step of selecting comprises the step of:

extracting the optimal down sampling phase from a tracking unit which has been tracking the CDMA channel.

20. The method of claim 15, wherein the step of selecting comprises the step of:

selecting an arbitrary sampling phase which is changed sequentially for each measurement.

21. The method of claim 15, wherein the arbitrary sampling phase is changed sequentially over four consecutive sampling phases.

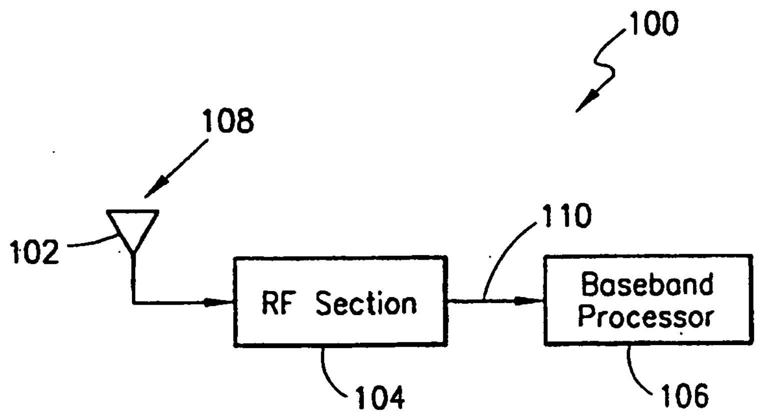


FIG. 1

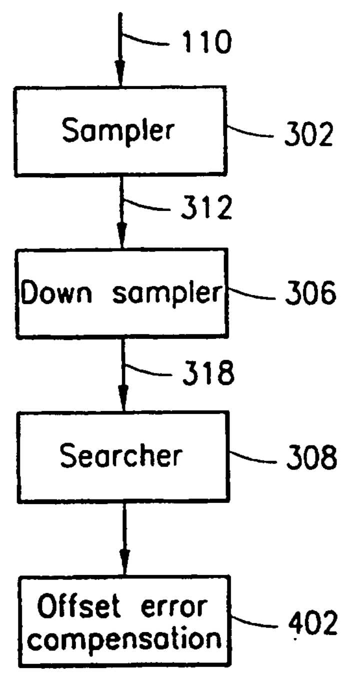


FIG. 4

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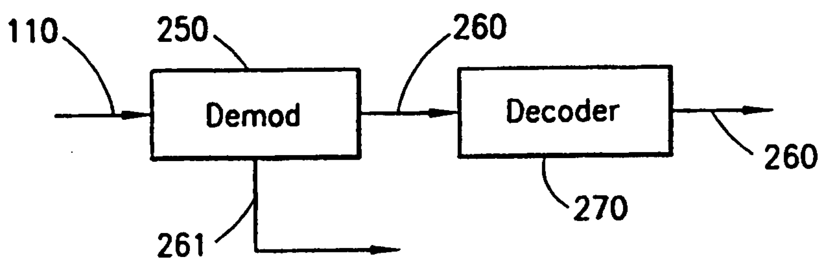

FIG. 2

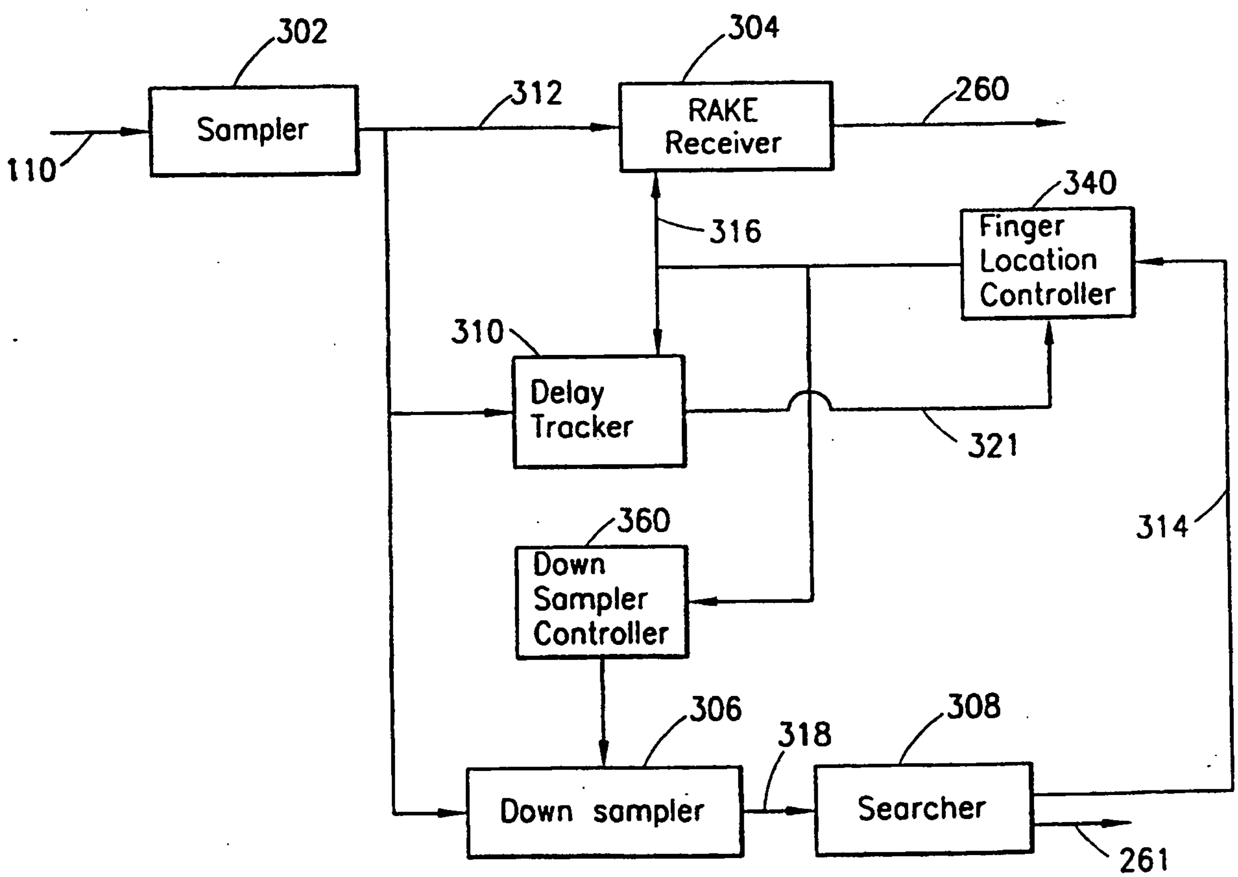

FIG. 3

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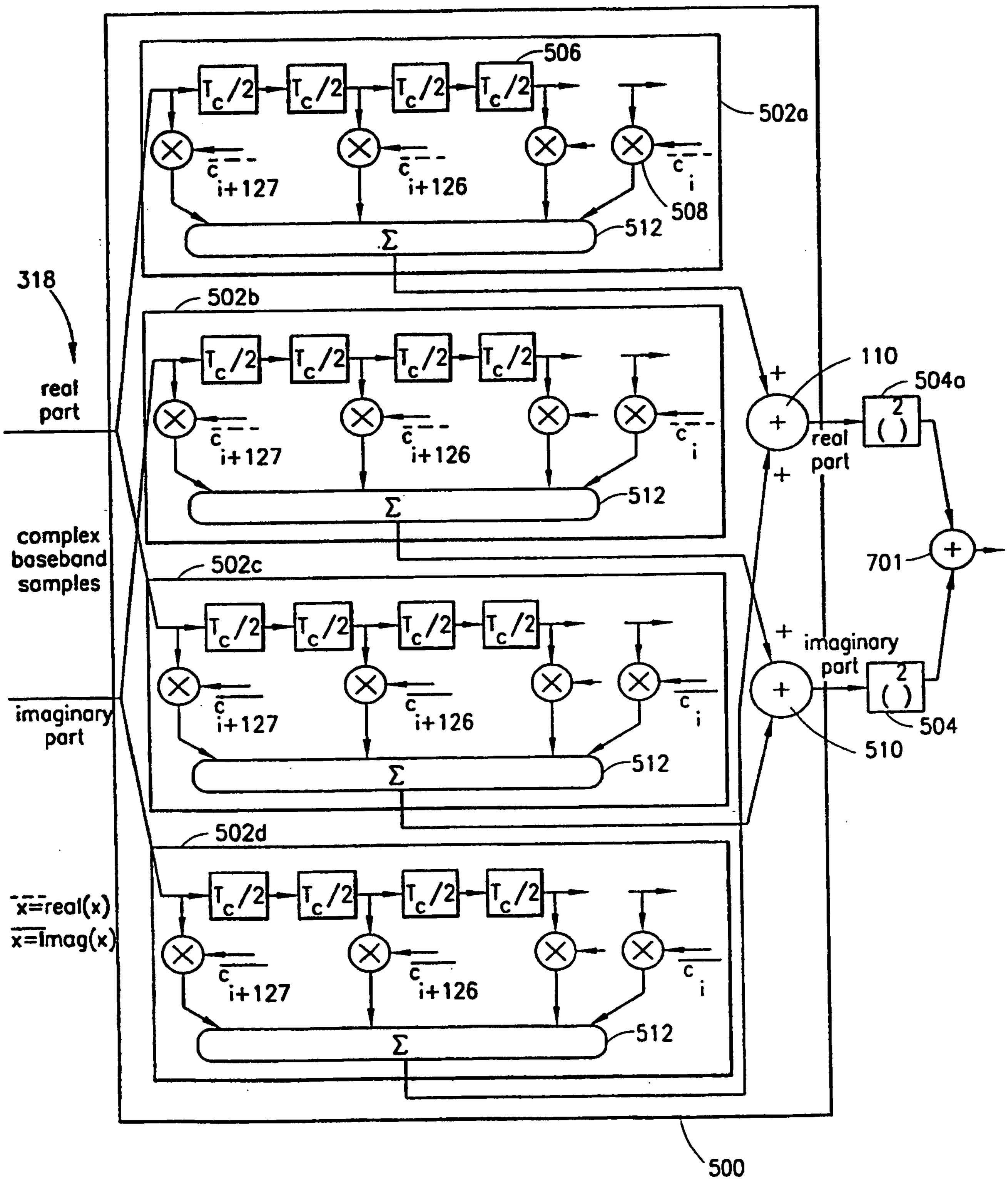

FIG. 5

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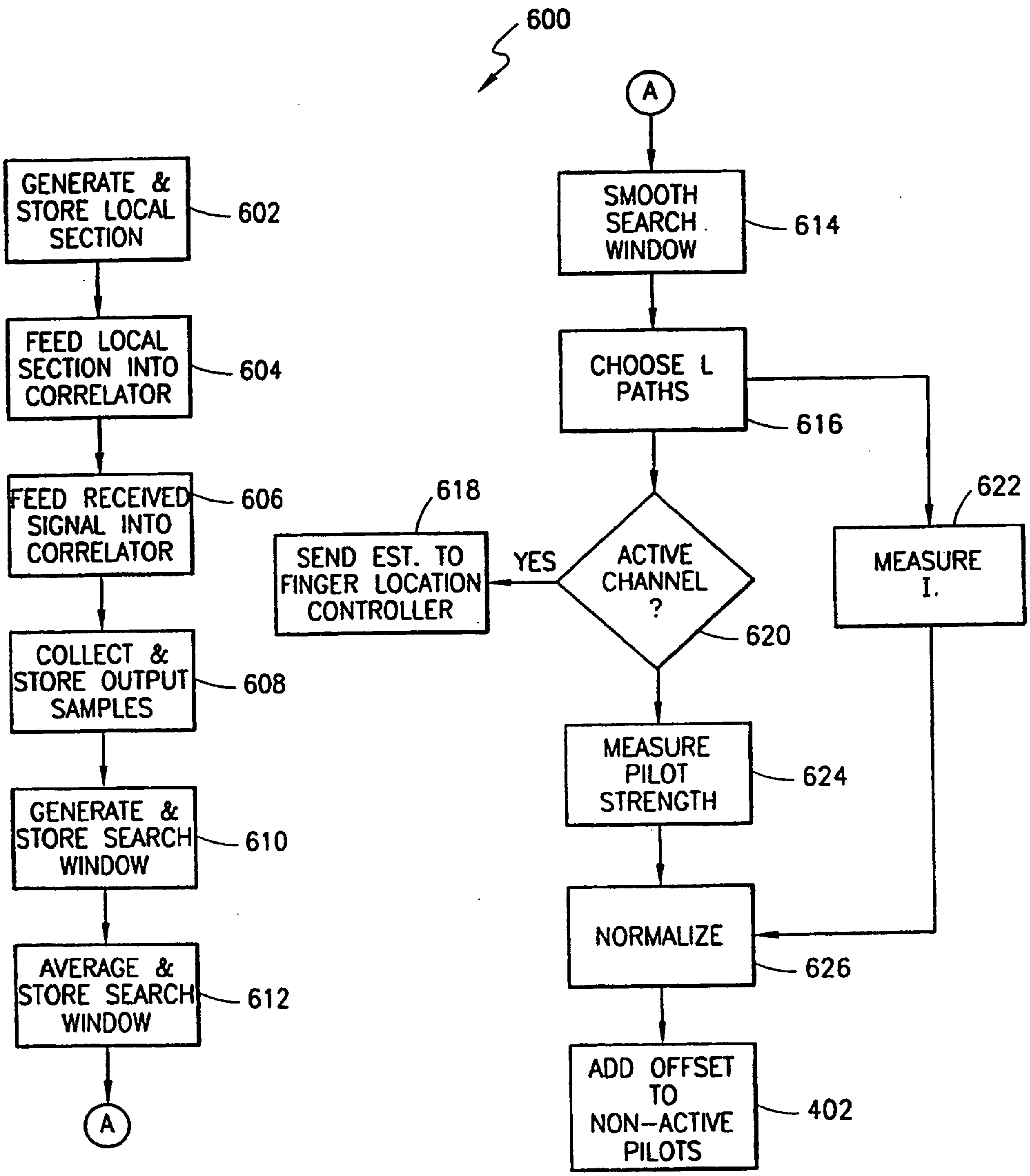

FIG. 6

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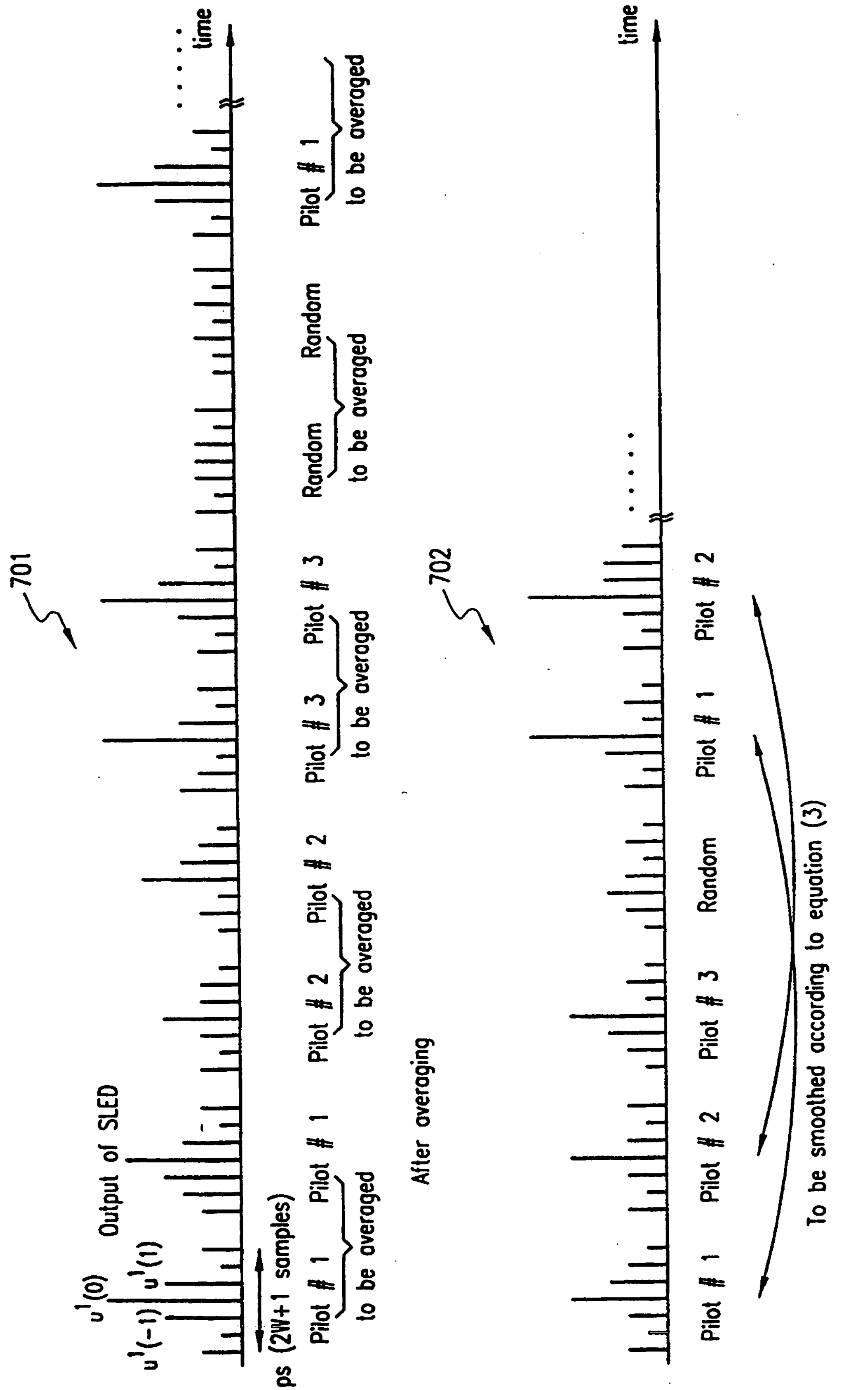

FIG. 7

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U1S S2204

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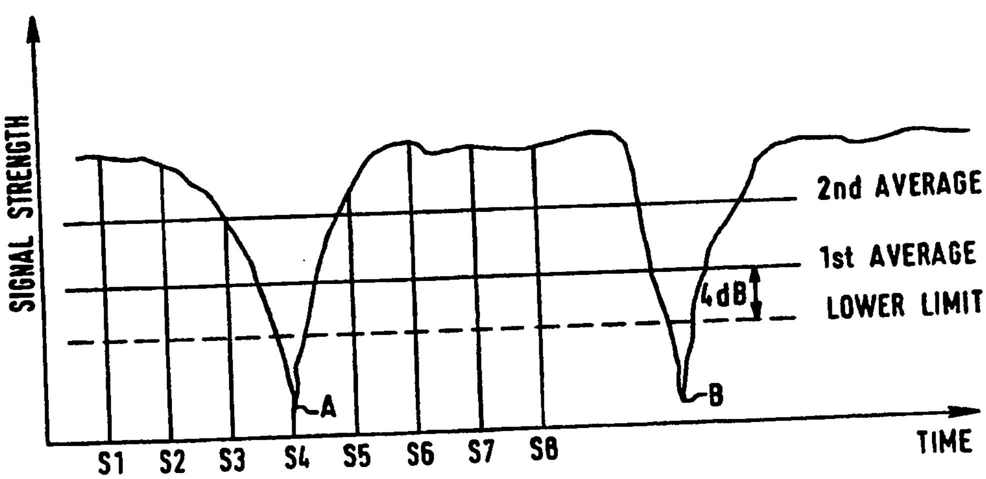
INT CL⁴ G01R 19/00 29/08, H04B 7/00

(54) **Radio field strength determination**

(57) To determine radio field strength using a mobile station at which fade outs such as at A and B, may happen due to multi-path interference, the signal strength is measured by obtaining samples S1, S2 etc, these values are used to obtain a first average value, a lower limit a pre-determined signal strength below the first average value is then defined and then a second average value is obtained by replacing the samples below the lower limit by the value of the lower limit itself. The second average is more representative of signal strength.

FIG.1.



At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

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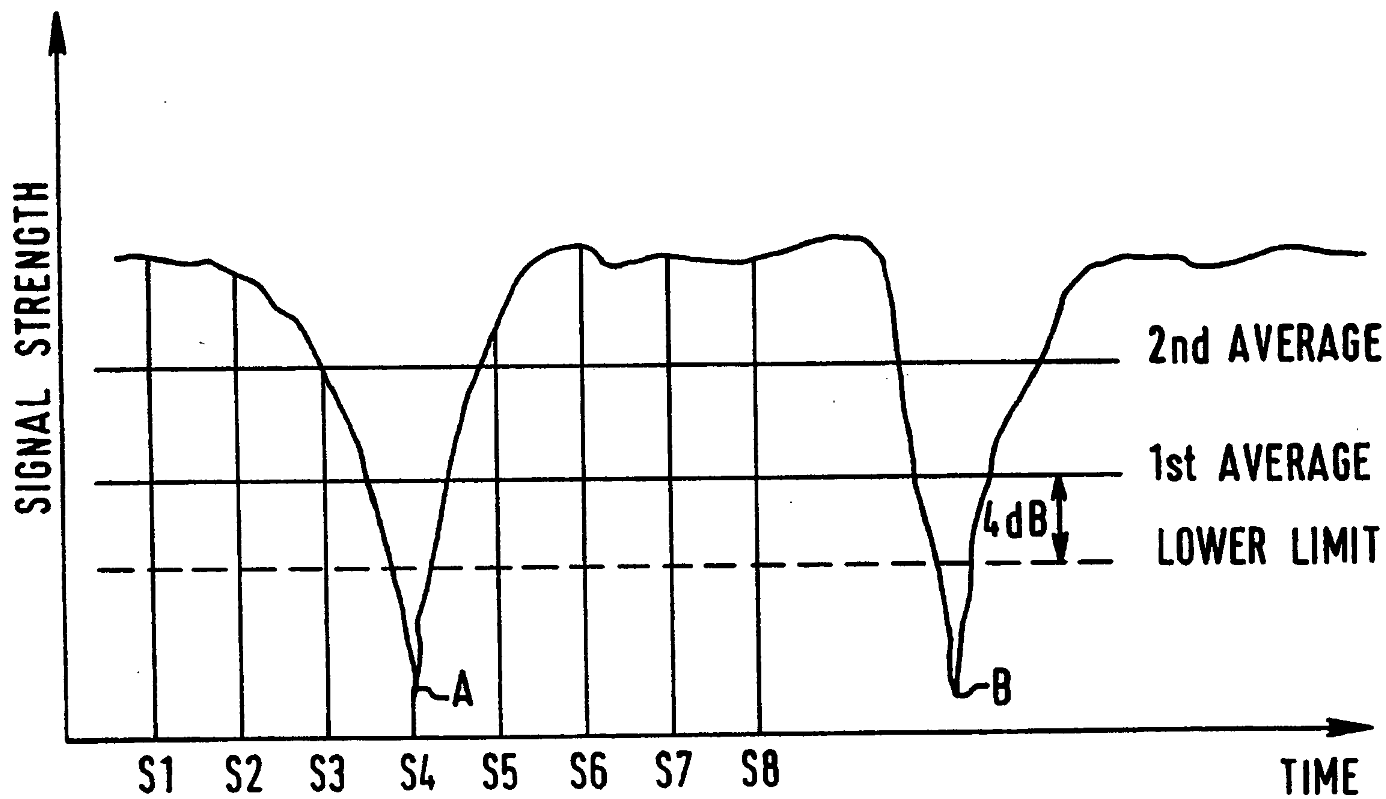
FIG. 1.



SIGNAL STRENGTH
2nd AVERAGE
1st AVERAGE
4dB
LOWER LIMIT
A
B
S1
S2
S3
S4
S5
S6
S7
S8
TIME

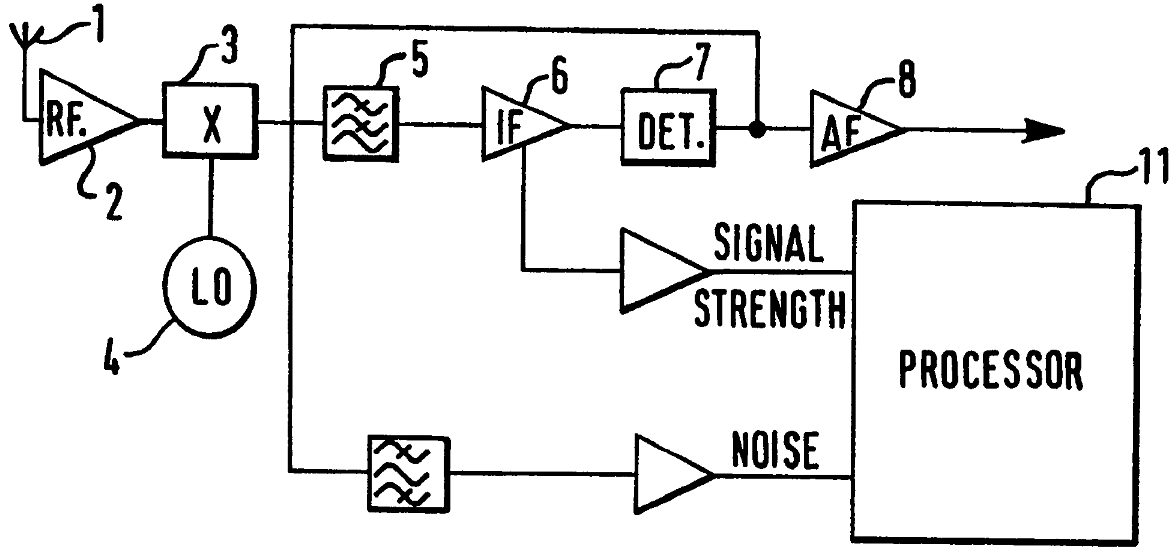

1
2
3
4
5
6
7
8
11
RF.
X
LO
IF
DET.
AF
SIGNAL
STRENGTH
NOISE
PROCESSOR

FIG. 2.

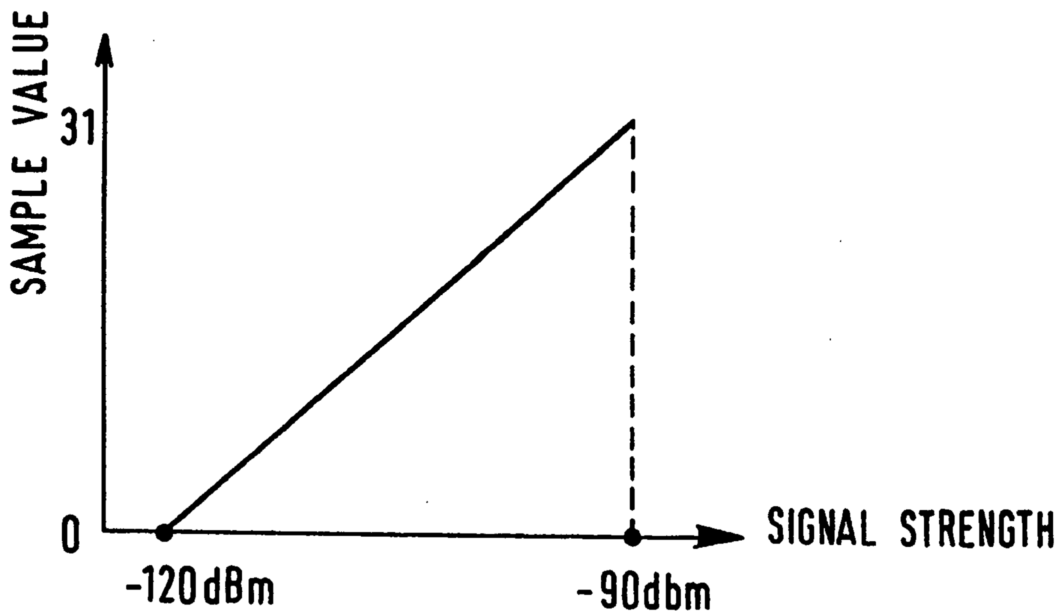

SAMPLE VALUE
31
0
-120dBm
-90dbm
SIGNAL STRENGTH

FIG. 3.

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RADIO COMMUNICATION APPARATUS

This invention relates to radio communication apparatus, and especially such apparatus including a mobile station for use with at least one base station.

For efficient operation in trunked mobile radio communication apparatus, it is necessary for the mobile to know the strength of received signals. The control channel which the mobile is receiving from a base station may become unusable and, to receive another one, the mobile may have to scan a large number of other control channels (transmitted from other base stations or from the same base station). This needs to be carried out as quickly as possible, but a problem arises if the mobile is in an environment where multi paths reflections from buildings instantaneously reduce to a large extent the signal strength (this is known as a Rayleigh fading environment).

If the signal strength is measured for a brief period which includes a rapid fade in signal strength, the minimum in signal strength may be such that the average signal strength measurement over that period is deemed too low to be usable. Nevertheless, apart from the rapid fade - and such rapid fades can be very deep reductions in signal strength - the average signal strength may be

usable for communication on a signal channel when such a channel is allocated: If the base station happened to transmit information to the mobile just at the instant of the fade when it might not be received, in many situations the information would simply be re-transmitted after a short interval.

The invention provides radio communication apparatus comprising a mobile station for communication with at least one base station, means for obtaining samples representative of the strength of the signal received at the mobile station on a channel transmitted by the base station, and processing means arranged to produce a 1st average value of signal strength from a pre-determined number of samples, to define a lower limit a pre-determined signal strength below the average, and to produce a 2nd average value of signal strength from the samples but without using any of the values that were below the lower limit.

The omission of values below the lower limit in the calculation of the second average results in a more realistic assessment of signal strength for the short measuring period available.

Radio communication apparatus comprising a mobile station for communication with at least one base station

will now be described by way of example with reference to the accompanying drawings, in which:

Figure 1 is a graph of typical signal strength variation with time;

Figure 2 is a diagram of part of the circuit of the mobile station;

Figure 3 is a graph indicating the relation between the signal strength and the sample values.

The mobile station is designed to communicate with several base stations in the usual way. The mobile communicates with each base station on several channel pairs, each consisting of an up-link and down-link, most of the channel pairs being for communication traffic, but one pair being for control purposes.

This invention is concerned with measurement of signal strength at the mobile of the communication channels of various base stations. In the event that the signal strength becomes unusable, the mobile communicates briefly with other communication channels in an order pre-determined by an algorithm.

When a channel is found which has an adequate signal

strength, the mobile now communicates with that channel.

Because the mobile is typically moving, the signal strength of a received channel varies with time. Often, the mobile will be in a vehicle moving in an urban environment between tall buildings. The mobile then receives the direct signal from the base station and/or reflected signals from various buildings. This so-called multi-path effect results brief but pronounced fades in signal strength e.g. at points, A,B.

While the signal strength at point A, B is too low to be usable, nevertheless this does not prevent the channel being usable as a control channel or for traffic purposes since apart from the very brief points A,B, the signal strength is sufficient. However, unless a long time average of the signal strength is made, a time average including the point A could well indicate that the channel is not usable.

In accordance with the invention, the pre-determined number of samples S1, S2 etc representative of the signal strength are obtained over a pre-determined period. The average (1ST AVERAGE) of the sample values is then calculated. Next a lower limit (L) is calculated which is a pre-determined signal strength below the calculated average (1ST AVERAGE). All of the samples lying below the

lower limit L are now replaced by values equal to the lower limit L. The average of the original samples together with those replaced by the lower limit value is now calculated (2ND AVERAGE).

It is found that the 2nd average is more useful as regards assessing signal strength than the 1st average value, in that the 1st average could be regarded too low to be usable whereas the 2nd, higher average may well not be.

As an example, the 1st average maybe of 8 samples, taken at intervals 3.75 milliseconds, the lower limit maybe 4db down on the first average. Naturally other numbers, samples, intervals or values of the lower limit relative to the first average maybe used.

The relevant parts of a circuit in a mobile to acomplish the above is illustrated in figure 2. The mobile receives signals by an antenna 1, and an r.f. amplifier 2 feeds signals to a mixer 3 feed from a local oscillator 4, and the resulting i.f. signals are band pass filtered by filter 5 and amplified i.f. amplifier 6. The audio signal is recovered by a detector 7, and amplified by an audio frequency amplifier 8.

The samples are based on both the r.f. signal

strength and on the noise of the signal in order that an assessment can still be made of signal strength even when, as at low signal strength, the noise predominates over the signal itself. This is known in itself. The noise signal is tapped from the output of the detector, and passes through a band pass filter 10, which passes 9kHz.

The r.f. signal is tapped from i.f. amplifier 6. Both signals are amplified and passed to processor 11.

The i.f. and noise signals are converted to digital form by an analogue to digital convertor. Each pair of digital values, representing i.f. and noise signals at a particular sampling instant, are fed to a look-uptable and a number between 0 and 31 is obtained representing signal strength.

The characterstic of the values of the samples related to r.f. signal strength as shown in figure 3. The values -90dBm and -120dBm indicate signal strengths as 90db down and 120db down on 1 milliwatt, respectively.

When the signal strength assessment is being performed, 8 sucessive sample numbers are obtained, and the processor calculates the average. The processor then calculates the nearest number (or the next number below) which would correspond to 4db below the average, and the

average is then re-calculated to obtain the 2nd average and hence a better assessment of signal strength.

The signal assessment method need not be used only when the signal becomes unusable. If it is desired to obtain repeated updates on signal strength, the method can be performed repeatedly.

CLAIMS

1. Radio communication apparatus comprising a mobile station for communication with at least one base station, means for obtaining samples representative of the strength of signal received at the mobile station on a channel transmitted by the base station, and processing means arranged to produce a 1st average value of signal strength from a pre-determined number of samples, to define a lower limit a pre-determined signal strength below the average, and produce a 2nd average value of signal strength from the samples but without using any of the values that were below the lower limit.

2. Radio communication apparatus as claimed in claim 1, in which the processing means is arranged to produce the 2nd average value using the samples but with any below the lower limit being replaced by that lower limit.

3. Radio comunication apparatus as claimed in claim 1 or claim 2, in which samples representative of the strength of the signal are in use calculated from values representative of the signal strength and the noise.

4. Radio communication apparatus as claimed in claim 3, in which the processing means include a look-uptable from which samples maybe obtained based on simultaneous samples of signal strength and of noise.

5. Radio communication apparatus substantially as herein before described with reference to the accompaning drawings.

6. A method of measuring signal strength at a mobile station that is suitable for communication with at least one base station, comprising obtaining samples representative of the strength of the signal, producing a first average value of signal strength from a pre-determined number of samples, defining a lower limit a pre-determined signal strength below the average, and producing a 2nd average value of signal strength from the samples but without using any of the values that were below the lower limit.

7. A method substantially as herein before described with reference to the accompanying drawings.

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